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PTO/SB/05 (12/97)

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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No. 042390.P6604

Total Pages 3

First Named Inventor or Application Identifier Kevin J. Lee

Express Mail Label No. EL034146512US

ADDRESS TO: Assistant Commissioner for Patents
Box Patent Application
Washington, D. C. 20231

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. X Fee Transmittal Form
(Submit an original, and a duplicate for fee processing)
2. X Specification (Total Pages 14)
(preferred arrangement set forth below)
 - Descriptive Title of the Invention
 - Cross References to Related Applications
 - Statement Regarding Fed sponsored R & D
 - Reference to Microfiche Appendix
 - Background of the Invention
 - Brief Summary of the Invention
 - Brief Description of the Drawings (if filed)
 - Detailed Description
 - Claims
 - Abstract of the Disclosure
3. X Drawings(s) (35 USC 113) (Total Sheets 4)
4. X Oath or Declaration (Total Pages 5)
 - a. Newly Executed (Original or Copy)
 - b. Copy from a Prior Application (37 CFR 1.63(d))
(for Continuation/Divisional with Box 17 completed) (Note Box 5 below)
 - i. DELETIONS OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
5. Incorporation By Reference (useable if Box 4b is checked)
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. Microfiche Computer Program (Appendix)

Electroplating Cell Based Upon Rotational Plating Solution Flow

Inventor: Kevin J. Lee

5 Field of the Invention

This invention is in the field of semiconductor processing. More specifically, the invention discloses a method for electroplating a material onto a semiconductor substrate.

Background of the Invention

10 A step in the fabrication of semiconductor integrated circuits is to apply a thin film of material onto the surface of a semiconductor substrate. The thin film is then patterned to form openings within the film. A second thin film of material is applied to the patterned thin film such that the second thin film fills the openings of the pattern in the first film. The second thin film is then patterned, and a third thin film is applied to the second thin film and is patterned, and the sequence is repeated until the desired integrated circuit structure is created.

15 The sequence for building an integrated circuit begins with a transistor structure formed on the semiconductor substrate. Alternating layers of electrically conducting and insulating thin film materials are formed over the transistor structure, and the electrically conducting film layers are interconnected to one another to form electrically conducting pathways throughout the integrated circuit. The conducting film material is commonly aluminum or an alloy of aluminum. Vapor deposition is the preferred method
20 for applying the conducting film to the surface of the substrate.

As technology advances toward faster speeds for integrated circuits, the widths of individual lines of the circuitry decrease in size. Although vapor deposition continues to be widely used for depositing films, new methods such as electroplating are being developed for depositing conductor films within tight spacings in a patterned film layer. Additionally, it becomes necessary to use conductors with reduced
25 resistance such as copper due to speed limitations posed by aluminum and alloys of aluminum.

A viable technique for forming a copper thin film layer on a patterned substrate surface is electroplating. A patterned semiconductor substrate is prepared for electroplating. The patterned film on

the semiconductor substrate may be an insulating film such as silicon dioxide. The patterned silicon dioxide contains openings to the underlying conductor film material. The underlying conductor film material may be copper or it may be another conductor material. To prepare for electroplating, a seed layer of material may be formed on the underlying conductor film material using vapor deposition.

5 Once prepared with the necessary seed layer, if any, the patterned semiconductor substrate is placed face down at the top end of an electroplating cup. A cathode contact is created on the edge of the substrate by coupling the substrate to the negative terminal of a power source. There is an anode at the bottom of the electroplating cup. The anode is coupled to the positive terminal of a power source. The substrate is clamped against an o-ring to form a watertight seal around the substrate perimeter. An inlet
10 pipe is inserted into the cup through the bottom of the cup, so that a nozzle at the end of the pipe is inside the cup and faces the substrate surface. A liquid electroplating solution flows through the inlet pipe and out of the nozzle, spraying a liquid jet of fluid directed perpendicularly toward the substrate surface. The electroplating solution contacts the substrate surface, the power supply is turned on, and a circuit is formed between the anode and cathode through the electroplating solution. The desired material is electroplated
15 onto the surface of the substrate.

One aspect of making electroplating a viable process for semiconductor fabrication is to form a uniformly deposited electroplated film layer. Utilizing the standard technique described above, film thickness uniformities of 6% can be achieved. However, for achieving desired process yields an even better uniformity is needed. Moreover, as the substrate size increases from 200 millimeters in diameter to
20 300 millimeters and beyond, it will be more difficult to attain electroplated film thickness uniformity using the currently known electroplating techniques. There are several factors causing non-uniformity in electroplating. One of the factors is lack of continuity of the cathode contact. This can be corrected by utilizing a cathodic contact ring at the edge of the substrate to form a continuous cathode contact. Another factor causing non-uniform electroplated film thickness is an accumulation of electrolytic solution on
25 surface points on the substrate due to the perpendicular transport of liquid to the substrate surface.

A way of improving electroplated film thickness uniformity was identified in U.S. Patent 4,304,641 "Rotary Electroplating Cell with Controlled Current Distribution". There the method was to use

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a flow-through jet plate having nozzles of increasing size and uniformly spaced radially therethrough or the same sized nozzles with varying radial spacing to provide a differential flow distribution of the plating solution. Additionally, the patent disclosed the technique of rotating the substrate by connecting the cathode to a spindle, which in turn is rotated by a motor. Alternatively, the cathode and anode can be
5 rotated at the same time. Rotating the substrate relative to the anode helps to create a more uniform distribution of electroplating solution over the surface of the substrate by preventing accumulation on contact from the liquid spray.

One problem with using a jet plate is that a jet plate must be specially fabricated with exact hole distribution and dimensions. This can significantly add to the cost of fabricating the electroplating
10 equipment. A problem with rotating the cathode and possibly the anode, of course, is the increased complexity of the equipment. Whenever there are moving parts in equipment, equipment maintenance becomes more complex and chances of mechanical failure are greater. Using a motor in the equipment drives the cost of the equipment up. Higher costs are desirably avoided because of the generally increasing costs of producing integrated circuits while prices of manufactured integrated circuit parts continue to
15 decrease.

It is therefore advantageous to use an electroplating technique that can improve the film thickness uniformity while at the same time avoiding increased cost and complexity to the electroplating equipment.

Summary of the Invention

The present invention discloses a method of applying a liquid material onto a substrate surface.
20 The liquid material is applied by placing the substrate surface within an enclosure, and introducing the liquid material into the enclosure. The liquid material is directed angularly toward the substrate surface so that the liquid material flows rotationally upon contact with the substrate surface.

In conjunction with the method, there is also described an apparatus for coating a substrate with a liquid material. There is a chamber having cylindrical interior walls, where the chamber has a first end and
25 an opposing second end. An opening in the first end holds the substrate. An inlet pipe having an end that is directed within the chamber is coupled to the second end of the chamber. A nozzle is coupled to the end

of the inlet pipe, through which the liquid material is sprayed generally toward the substrate surface, wherein the liquid material flows rotationally upon contact with the substrate.

Brief Description of the Drawings

The drawings are provided to enable the reader to help understand the workings of the invention through example only, and are not set forth as visual limitations of the present invention. The drawings are described briefly as:

Fig. 1A is a cross-sectional view of a substrate held in an enclosure with a liquid spraying onto the substrate.

Fig. 1B is a top view of the substrate surface, representing lines of liquid flow as the liquid contacts the substrate surface.

Fig. 1C is a top view of the nozzle through which liquid spray emanates.

Fig. 1D is a side view of a single liquid spray outlet to demonstrate an angle θ by which the liquid may be sprayed.

Fig. 1E is a side view of a single liquid spray outlet to demonstrate an alternative way of achieving the angle θ shown in Fig. 1D.

Fig. 1F is a side view of a single liquid spray outlet to demonstrate an alternative angle ϕ by which the liquid may be sprayed.

Fig. 2 is a cross-sectional view of an application of the present invention in an electrochemical cell.

Description of the Preferred Embodiments

The present invention provides a technique for coating a substrate with a liquid material in such a way that the liquid material forms a coating with acceptable thickness uniformity across the substrate while avoiding the use of rotary or other mechanical motion to create a rotational liquid material flow. The invention is useful for electroplating or for other manufacturing processes where a liquid is applied to a substrate surface. The inventive method includes directing the liquid material angularly toward the substrate surface. The invention will be described in more detail below. To facilitate a description, the context for description is set forth in the field of semiconductor manufacturing, more specifically an electrochemical cell for electroplating metal, in particular, copper, on a semiconductor substrate. Any

reference to “approximate” dimensions should be construed as the designated dimension plus or minus variation within tolerances that would be reasonable according to the judgment of a person of ordinary skill in the art, in the context of using a given embodiment of the invention.

Referring to Fig. 1A, there is provided a substrate 10 within an enclosure 20. Enclosure 20 contains cylindrical walls 30. Substrate 10 is a semiconductor wafer with a surface 40 containing a pattern (pattern not shown). Substrate 10 is secured to the top end 50 of enclosure 20. Substrate surface 40 faces a nozzle 60. Nozzle 60 directs liquid solution 70 out of nozzle 60 toward surface 40. Nozzle 60 contains four spray outlets 90, 92, 100, 102 which direct liquid 70 at an angle from perpendicular. The resulting flow of liquid 70 on surface 40 is a rotational pattern.

Fig. 1B sketches the theoretical shape of liquid 70 as it flows on surface 40. Flow lines are shown to extend in a curve and radially outward toward the perimeter 110 of surface 40.

Fig. 1C is a top view of nozzle 60 containing four spray outlets 90, 92, 100, 102 where each pair of spray outlets 90, 92, 100, 102 are at opposite sides of a cross shape. Each spray outlet 90, 92, 100, 102 sprays liquid out of nozzle 60 in the general direction of substrate 10 (Fig. 1A).

Fig. 1D is a side view of nozzle 60 with spray outlet 100 emanating therefrom. Spray outlet 100 is preferably a cylindrical pipe having an elbow joint 125 and a shoulder joint 145. Spray outlet 100 is angled away from vertical by angle θ 115. Angle θ is preferably in a range of 20 to 60 degrees from vertical. Nozzle 60 is held in the vertical direction. Angle θ 115 can be formed by bending elbow joint 125 outward radially away from nozzle 60. Spray outlet 100 is attached to nozzle 60 at the shoulder joint 145. Shoulder joint 145 is held at an approximately 90-degree angle with respect to the vertically-shown nozzle 60.

Alternatively, Fig. 1E is a side view of nozzle 60 containing one spray outlet 100. Spray outlet 100 is angled outward from nozzle 60 in a similar radial angular direction θ 115 as in Fig. 1D. Although the angle shown herein is about 45 degrees, the angle is preferably in a range of approximately 20 to 60 degrees from vertical. Nozzle 60 is held in the vertical direction. Spray outlet 100 is preferably a cylindrical pipe having an elbow joint 120 and a shoulder joint 140. Elbow joint 120 is shown here to be angled at approximately 90 degrees. Instead of bending spray outlet 100 outward by angling the elbow

joint as in Fig. 1D, angle θ 115 is formed by angling shoulder joint 140 relative to nozzle 60. Liquid flow 70 emanating from elbow joint 125, 120 in either Figs. 1D or 1E is directed radially outward from nozzle 60, so that liquid contacts cylindrical walls 30 of enclosure 20 (Fig. 1A). When in contact with cylindrical walls 30, liquid flow 70 rotates according to the shape of cylindrical walls 30.

5 Still alternatively, as shown in Fig. 1F, spray outlet 150 is shown to be angled at approximately 45 degrees from vertical, in an angular direction ϕ 160. Preferably, angular direction ϕ is directed such that liquid spray emanates from spray outlet 150 at approximately 20 to 60 degrees from vertical. However, unlike Figs. 1D and 1E, angular direction ϕ is formed by twisting spray outlet 150 at shoulder joint 170. Elbow joint 165 and shoulder joint are both at approximately 90 degrees. Spray outlet 150 is therefore
10 angled sideways if one is facing nozzle 60 and spray outlet 150. Liquid spray emanating from spray outlet 150 would thus be directed circumferentially toward the substrate surface.

Referring to Fig. 2, an application for the present invention is shown. An electrochemical cell 200 for electroplating a copper film on a semiconductor substrate 230 is provided in cross-sectional view. Electrochemical cell 200 includes a cup 210 inside which the electrochemical reactions occur. An opening
15 220 in the top end of cup 210 holds semiconductor substrate 230 face down on the rim 240 of cup 210. The surface of substrate 230 to be plated faces the interior of cup 210. An o-ring 250 provides a seal to prevent liquid from leaking out from the perimeter of substrate 230. Substrate 230 is in contact with a cathode 260, which in the present embodiment is preferably a continuous ring cathode. Cathode 260 is secured within rim 240 of cup 210 to prevent cathode 260 from moving about. Centering ring 270
20 positions substrate 230 in place. Exit slots 275 allow liquid solution to exit cup 210. Cylindrical walls 280 are electrically non-conductive. The anode 290 is coupled to positive terminal of power supply (not shown). Cathode 260 is coupled to the negative terminal of the power supply.

A pipe 300 is introduced through the bottom end of cup 210 through a hole 310. A gasket 320 forms a plug to prevent liquid from leaking down through the bottom of cup 210. Pipe 300 is capped on
25 the pipe top end 330. Four spray outlets 340, 342, 344, 346 and a fifth spray outlet 348 extend outward from top end 330 to form a nozzle. Four spray outlets 340, 342, 344, 346 form elbow joints 350, and are twisted at their shoulder joints 360 to form a sideways angle ϕ 365. Angle ϕ 365 is preferably

approximately 20 to 60 degrees from vertical. Fifth spray outlet 348 is shown as a straight extension outward from the center of pipe top end 330 so that liquid spray emanating therefrom is directed at an angle perpendicular to substrate surface 230 being held directly above. The purpose of fifth spray outlet 348 is to prevent a void from forming in the vortex of the electroplating liquid as it sprays against substrate 230 in a rotational flow manner. Spray outlets 340, 342, 344, 346 direct liquid at a sideways angle with respect to pipe 300. Alternatively, and not shown in Fig. 2, spray outlets 340, 342, 344, 346 may be angled radially outward from pipe 300. Liquid spray emanating from four spray outlets 340, 342, 344, 346, respectively, contacts substrate surface 230 at an angle to create a rotational liquid flow effect on substrate surface 230.

The electrochemical cell described in reference to Fig. 2 can be used to form a copper film on a silicon wafer. An electrical current applied to cathode 260 creates a current density of approximately 0.5 to 5 amps per square decimeter on substrate 230. Substrate 230 in this example is a silicon wafer of a diameter of 200 millimeters. Dimensions within the electrochemical cell depend on the shape and size of the substrate being treated. Substrate 230 is held at a distance of approximately 3 to 5 centimeters from the tips of spray outlets 340, 342, 344, 346. Cup 210 is approximately 190 millimeters in inner diameter and approximately 10 centimeters in depth. Inlet pipe 300 extends inward approximately 2 to 4 centimeters from the bottom of cup 210 interior. Liquid solution consisting of commercially available acid-copper plating bath is introduced to cup 210 at a flow rate of approximately 10 to 40 liters per minute. The liquid solution is directed at an angle ϕ 365 of approximately 20 to 60 degrees away from vertical, to cause liquid to contact substrate 230 in a rotational direction. A copper film forms on substrate 230.

The embodiments of the present invention demonstrate the advantages of the invention in its simplicity for achieving an acceptably uniform coating on the surface of a substrate. Moving parts are not needed for directing the liquid spray, nor are there complex hole patterns in the anode. Note that the invention is not at all limited to electroplating, to a semiconductor substrate, or for that matter, to semiconductor processes. A person of ordinary skill in the art can experiment with angles, the number of spray outlets and other factors such as liquid flow rate and distance from the spray outlet to the substrate surface, to achieve the desired uniformity of thickness of material coated on the substrate. The nozzle may

be different from that described here. For example, there could be a pipe inlet into the cup, where the pipe has a ribbon cutout instead of spray outlets. Nothing herein should be interpreted to be reducing the spirit or scope of the invention. To the extent details are described, such details are provided for facilitation of understanding the invention, the invention being limited only by the claims below.

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Claims

I claim:

1. A method of applying a liquid material onto a substrate surface, comprising the steps of:

- 5 placing the substrate surface within an enclosure;
 introducing the liquid material into the enclosure; and
 directing the liquid material angularly toward the substrate surface so that the liquid material
flows rotationally upon contact with the substrate surface.

2. A method of applying a liquid material as in claim 1, further comprising the steps of:

- 10 pressing the substrate against the enclosure to form a seal.

3. A method of applying a liquid material as in claim 1, further comprising the steps of:

- providing a cathode contact;
 coupling the cathode contact to the substrate surface;
 providing an anode coupled to the cathode; and
15 wherein the liquid material is an electrolytic bath to form an electrochemical cell.

4. A method of applying a liquid material as in claim 3, further comprising the step of:

 forming a metallic film on the substrate surface.

5. A method of applying a liquid material as in claim 4, wherein the metallic film includes copper.

6. An apparatus for coating a substrate with a liquid material, comprising:

- 20 a chamber having cylindrical interior walls, said chamber having a first end and an opposing
second end;
 an opening in the first end for holding the substrate;
 an inlet pipe coupled to the second end, the inlet pipe having an end that is directed within the
chamber;
25 a nozzle coupled to the end of the inlet pipe, through which the liquid material is sprayed toward
the substrate surface, wherein the liquid material flows rotationally upon contact with the substrate.

7. An apparatus for coating a substrate as in claim 6, wherein said nozzle further comprises a spray outlet having an elbow joint.

8. An apparatus for coating a substrate as in claim 6 wherein said liquid is sprayed out of said nozzle at an angle of approximately 20 to 60 degrees from vertical.

5 9. An apparatus for coating a substrate as in claim 8, wherein said liquid is directed toward the chamber interior walls.

10. An apparatus for coating a substrate as in claim 8, wherein said liquid is directed circumferentially with respect to the substrate surface.

11. An apparatus for electroplating a material onto a substrate surface, comprising:

10 a chamber having cylindrical interior walls;

a holder for securing the substrate in place so that the substrate surface is directed into the interior of the chamber;

a cathode contact coupled to the substrate;

an anode coupled to the cathode;

15 a liquid electroplate bath introduced to the chamber through an inlet pipe;

a nozzle having a plurality of spray outlets on the inlet pipe, the spray outlets being directed angularly toward the substrate surface so that the anodic liquid electroplate flows rotationally upon contact with the substrate surface.

20 12. An apparatus as in claim 11, wherein said spray outlets are angled at approximately 20 to 60 degrees from vertical.

13. An apparatus as in claim 11, wherein said spray outlets are pointed radially outward with respect to the center of the substrate surface.

14. An apparatus as in claim 11, wherein said spray outlets are pointed circumferentially with respect to a perpendicular direction toward the substrate surface.

25 15. An apparatus as in claim 11, wherein said plurality of spray outlets comprises at least four spray outlets.

16. An apparatus as in claim 11, wherein said plurality of spray outlets further includes at least one spray outlet pointed perpendicularly toward the substrate surface.

17. An apparatus as in claim 16, wherein said at least one spray outlet is directed toward the center of the substrate surface.

5 18. A method of electroplating a material onto a substrate surface within an enclosed chamber, comprising the steps of:

securing the substrate within an opening in the chamber so that the substrate surface faces the chamber interior;

coupling a cathode to the substrate surface;

10 coupling an anode to the cathode; and

introducing a liquid electrochemical bath to the chamber interior and directing the liquid toward the substrate surface so that the liquid flows rotationally upon contact with the substrate surface.

19. A method of electroplating a material as in claim 18, wherein the step of introducing a liquid further includes spraying the liquid out of a plurality of spray outlets.

15 20. A method of electroplating a material as in claim 19, wherein the spray outlets are directed angularly toward the substrate surface.

21. A method of electroplating a material as in claim 20, wherein the spray outlets are angled at approximately 20 to 60 degrees from vertical.

20 22. A method of electroplating a material as in claim 21, wherein said liquid is directed radially outward with respect to the center of the substrate surface.

23. A method of electroplating a material as in claim 22, wherein said liquid is directed circumferentially with respect to a perpendicular direction toward the substrate surface.

24. A method of electroplating a material as in claim 19, wherein at least one of the plurality of spray outlets is pointed in a perpendicular direction toward the center of the substrate surface.

25 25. A method of electroplating a material as in claim 24, wherein said plurality of spray outlets includes at least four spray outlets forming a cross pattern.

26. A method of electroplating a material as in claim 25, wherein said plurality of spray outlets further includes at least one spray outlet located at the center of the cross pattern.

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Abstract

The invention discloses a method of electroplating a material onto a semiconductor substrate. A substrate is placed in a cylindrical processing chamber enclosure. A nozzle for spraying a liquid electroplating solution opposes the top surface of the substrate. The electroplating solution flows through the nozzle and outward angularly from the tip of the nozzle, so that the solution flows rotationally on the surface of the substrate.

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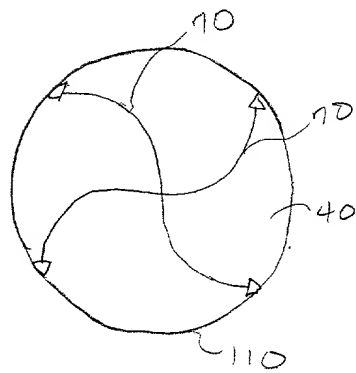
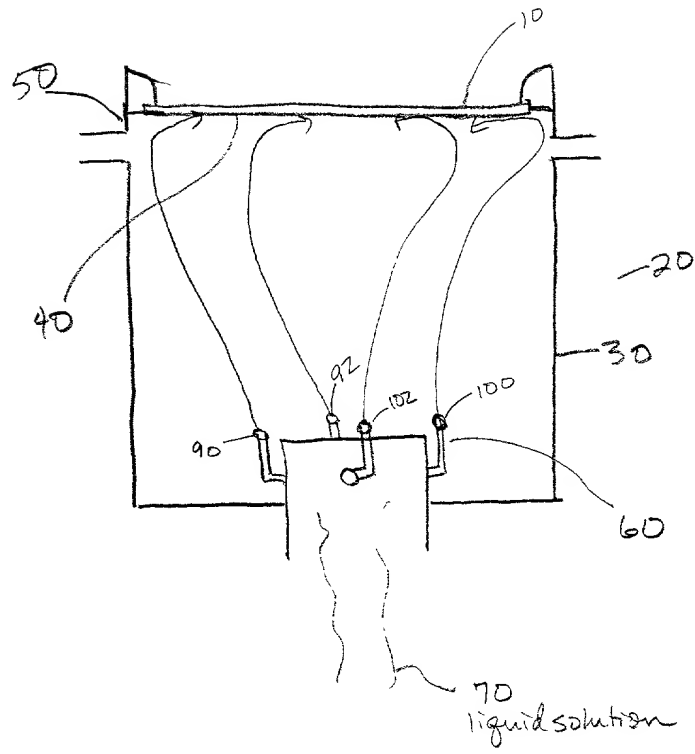


Fig. 1C

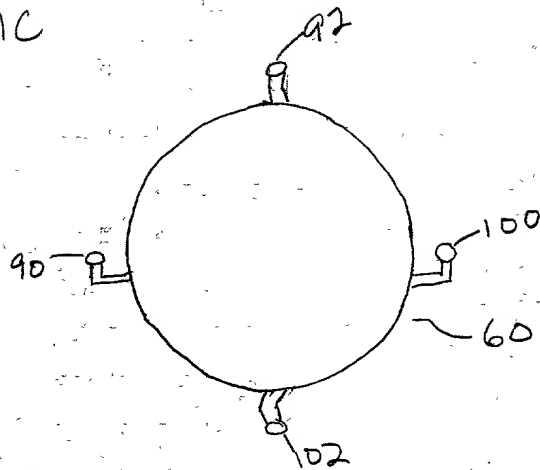


Fig. 1D

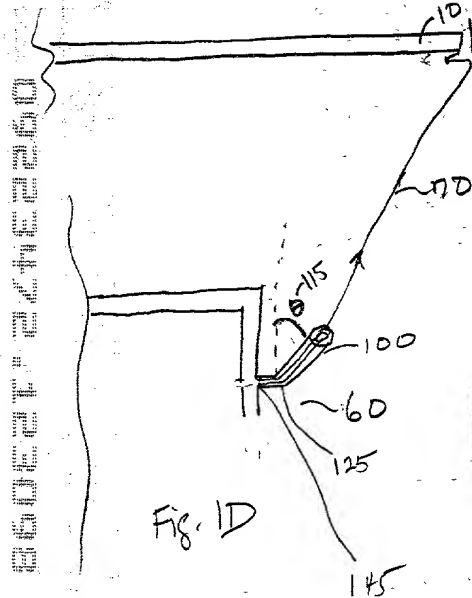
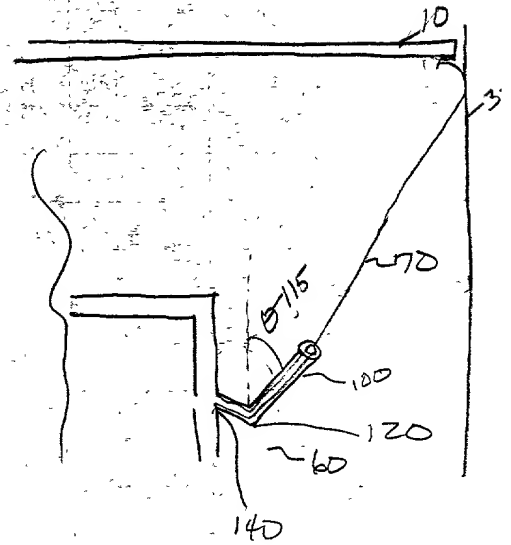


Fig. 1E



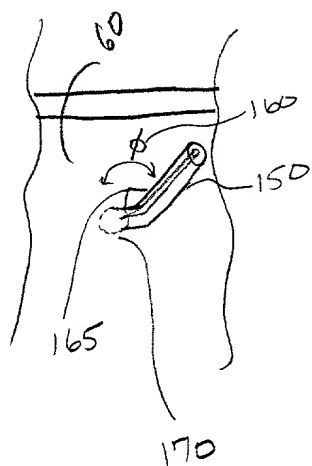


Fig-1F

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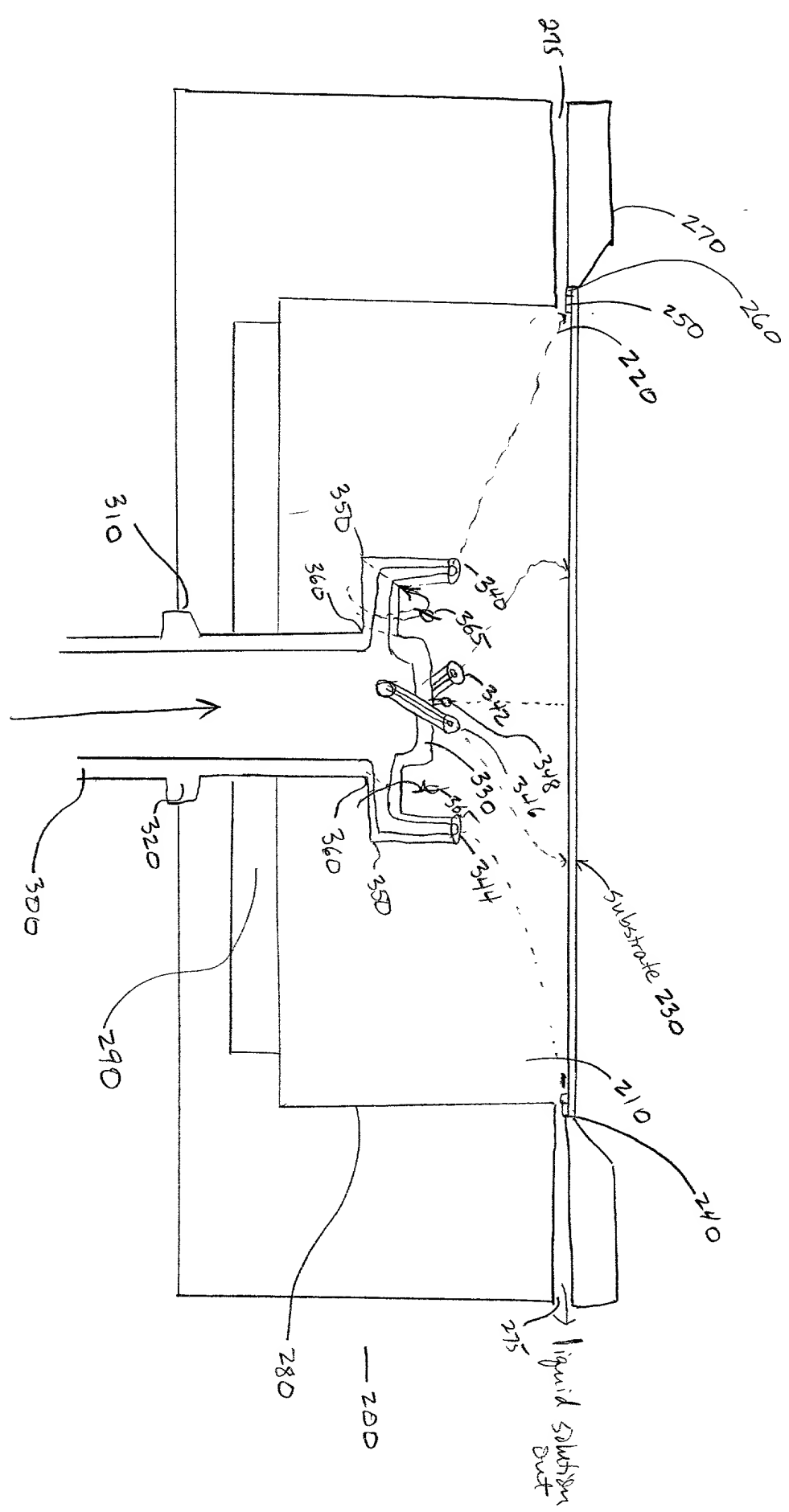


Fig. 2

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(FOR INTEL CORPORATION PATENT APPLICATIONS)**

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below, next to my name.

I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

ELECTROPLATING CELL BASED UPON ROTATIONAL PLATING SOLUTION FLOW

the specification of which

 X is attached hereto.
 was filed on _____ as
United States Application Number _____
or PCT International Application Number _____
and was amended on _____
(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment referred to above. I do not know and do not believe that the claimed invention was ever known or used in the United States of America before my invention thereof, or patented or described in any printed publication in any country before my invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, and that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months (for a utility patent application) or six months (for a design patent application) prior to this application.

I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d), of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

<u>Prior Foreign Application(s)</u>			<u>Priority Claimed</u>	
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<u>Yes</u>	<u>No</u>
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<u>Yes</u>	<u>No</u>
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<u>Yes</u>	<u>No</u>

I hereby claim the benefit under title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below

_____ (Application Number)	_____ Filing Date
_____ (Application Number)	_____ Filing Date

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

_____ (Application Number)	_____ Filing Date	_____ (Status -- patented, pending, abandoned)
_____ (Application Number)	_____ Filing Date	_____ (Status -- patented, pending, abandoned)

I hereby appoint Farzad E. Amini, Reg. No. P42,261; Aloysius T. C. AuYeung, Reg. No. 35,432; Amy M. Armstrong, Reg. No. P42,265; William Thomas Babbitt, Reg. No. 39,591; Carol F. Barry, Reg. No. P41,600; Jordan Michael Becker, Reg. No. 39,602; Bradley J. Bereznak, Reg. No. 33,474; Michael A. Bernadicou, Reg. No. 35,934; Roger W. Blakely, Jr., Reg. No. 25,831; Gregory D. Caldwell, Reg. No. 39,926; Kent M. Chen, Reg. No. 39,630; Lawrence M. Cho, Reg. No. 39,942; Yong S. Choi, Reg. No. P43,324; Thomas M. Coester, Reg. No. 39,637; Roland B. Cortes, Reg. No. 39,152; Barbara Bokanov Courtney, Reg. No. P42,442; Michael Anthony DeSanctis, Reg. No. 39,957; Daniel M. De Vos, Reg. No. 37,813; Robert Andrew Diehl, Reg. No. 40,992; Tarek N. Fahmi, Reg. No. 41,402; James Y. Go, Reg. No. 40,621; Richard Leon Gregory, Jr., P42,607; Dinu Gruia, Reg. No. P42,996; David R. Halvorson, Reg. No. 33,395; Thomas A. Hassing, Reg. No. 36,159; Phuong-Quan Hoang, P41,839; Willmore F. Holbrow III, Reg. No. P41,845; George W. Hoover II, Reg. No. 32,992; Eric S. Hyman, Reg. No. 30,139; Dag H. Johansen, Reg. No. 36,172; William W. Kidd, Reg. No. 31,772; Michael J. Mallie, Reg. No. 36,591; Andre L. Marais, under 37 C.F.R. § 10.9(b); Paul A. Mendonsa, Reg. No. P42,879; Darren J. Milliken, P42,004; Thanh V. Nguyen, P42,034; Kimberley G. Nobles, Reg. No. 38,255; Michael A. Proksch, Reg. No. P43,021; Babak Redjaian, P42,096; James H. Salter, Reg. No. 35,668; William W. Schaal, Reg. No. 39,018; James C. Scheller, Reg. No. 31,195; Anand Sethuraman, Reg. No. P43,351; Charles E. Shemwell, Reg. No. 40,171; Maria McCormack Sobrino, Reg. No. 31,639; Stanley W. Sokoloff, Reg. No. 25,128; Allan T. Sponseller, Reg. No. 38,318; Geoffrey T. Staniford, P43,151; Judith A. Szepesi, Reg. No. 39,393; Vincent P. Tassinari, Reg. No. P42,179; Edwin H. Taylor, Reg. No. 25,129; George G. C. Tseng, Reg. No. 41,355; Lester J. Vincent, Reg. No. 31,460; John Patrick Ward, Reg. No. 40,216; Stephen Warhola, Reg. No. P43,237; Ben J. Yorks, Reg. No. 33,609; and Norman Zafman, Reg. No. 26,250; my attorneys, of BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP, with offices located at 12400 Wilshire Boulevard, 7th Floor, Los Angeles, California 90025, telephone (310) 207-3800, and Alan K. Aldous, Reg. No. 31,905; Robert D. Anderson, Reg. No. 33,826; Joseph R. Bond, Reg. No. 36,458; Richard C. Calderwood, Reg. No. 35,468; Cynthia Thomas Faatz, Reg. No. 39,973; Sean Fitzgerald, Reg. No. 32,027; Seth Z. Kalson, Reg. No. 40,670; David J. Kaplan, Reg. No. 41,105; Leo V. Novakoski, Reg. No. 37,198; Naomi Obinata, Reg. No. 39,320; Thomas C. Reynolds, Reg. No. 32,488; Steven P. Skabrat, Reg. No. 36,279; Howard A. Skaist, Reg. No. 36,008; Steven C. Stewart, Reg. No. 33,555; Raymond J. Werner, Reg. No. 34,752; and Charles K. Young, Reg. No. 39,435; my patent attorneys, and Jeffrey S. Draeger, Reg. No. 41,000; Thomas Raleigh Lane, Reg. No. P42,781; Calvin E. Wells, Reg. No. P43,256; and Alexander Ulysses Witkowski, Reg. No. P43,280; my patent agents, of INTEL CORPORATION; and James R. Thein, Reg. No. 31,710, my patent attorney; with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith.

Send correspondence to Michael A. Bernadicou, BLAKELY, SOKOLOFF, TAYLOR &
(Name of Attorney or Agent)
ZAFMAN LLP, 12400 Wilshire Boulevard, 7th Floor, Los Angeles, California 90025 and direct
telephone calls to Michael A. Bernadicou, (408) 720-8598.
(Name of Attorney or Agent)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full Name of Sole/First Inventor Kevin J. Lee
Inventor's Signature _____ Date _____
Citizenship USA
(Country)
Post Office Address (Business or Residence or P.O. Box) _____
7793 SW 172nd Place, Beaverton, OR 97007

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Full Name of Sole/Third Inventor _____
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Title 37, Code of Federal Regulations, Section 1.56
Duty to Disclose Information Material to Patentability

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclose information exists with respect to each pending claim until the claim is cancelled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is cancelled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclose all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

- (1) Prior art cited in search reports of a foreign patent office in a counterpart application, and
- (2) The closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made of record in the application, and

- (1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim; or
- (2) It refutes, or is inconsistent with, a position the applicant takes in:
 - (i) Opposing an argument of unpatentability relied on by the Office, or
 - (ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

- (1) Each inventor named in the application;
 - (2) Each attorney or agent who prepares or prosecutes the application; and
 - (3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.
- (d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.